Background:

With a increasing demand on the global power grid and increasing energy costs there is a growing demand for change in the way we use energy. With a major portion of our energy produced going to the lighting of homes and office buildings a change here would significantly reduce our energy needs in the future. A new lighting system will decrease our demand on energy and will provide a secondary benefit by providing lower energy bills for our clients.

Introduction:

For ECE 403/405 our group was given the task of developing a lighting system using high-brightness LEDs.

Requirements:

- The LED array should provide light comparable to conventional lighting used today.
- Our lighting source must be powered by the 120 volts from a wall outlet.
- The light output of our LED array must be adjustable.
- Our LED array must be protected from over-current.
- We will compare light output, efficiency, cost, and life expectancy of all current forms of lighting with our LED array.

Design Considerations:

One of the first things we had to do to answer this goal was to choose a light emitting diode (LED) that would provide a high luminous flux to watt ratio to keep with our goal of increased lighting efficiency. One of the most crucial aspects of our project was the LEDs brightness and efficiency. Deciding to exceed the light output of a 100 watt light bulb which produces 1740 lumens a proper LED selection is a fundamental portion of our requirements. The LEDs that we looked at varied between one, three, and five watts, and anywhere 40 to 250 lumens. When choosing which LED to use we would need to consider cost, thermal efficiency, the viewing angle, the size of the LED, and life expectancy.

The goal of this project isn’t to replace current lighting sources with one using high-brightness LEDs. The LED technology isn’t as efficient as the fluorescent tube yet, however, in the past few years they have been gaining ground. That being said it is important that we try to find an LED that is the most efficient so we can compare our LED light source to current ones, and at the same time keeping in a reasonable price range. If the LEDs would get too hot, we would need to use a heat sink. This would add to the cost, but help the efficiency. The view angle of the LEDs is important, because the wider the angle, the butter the LEDs will add when we put them in a string. To reproduce

the light of a standard light bulb, we will need to have a string of LEDs. One light bulb produces 1740 lumens, and if one LED produces 100 lumens it will take more than 18 LEDs to produce as much light as the light bulb. The luminescent intensity doesn't directly add, because all the light from each LED doesn't necessarily intersect. The wider the viewing angle, the more the light will intersect, and the more total luminescent intensity our string will have.

The most appealing characteristic of LEDs are their Life expectancy. If operated at rated conditions, a high-brightness LED will run from anywhere between 20 to 60 thousand hours, the average light bulb lasts for about 900 hours. Turning an LED on and off, doesn't shorten the lifespan of the LED either. In addition to a longer lifespan LEDs are not subject to sudden burn out. There is no point in time at which the light source ceases to function; instead, the LEDs gradually degrade in performance over time. This is why there is a push to develop more efficient LEDs, and as long as we don't run the LED too hot, the LEDs should last for a very long time.

The next thing we took into consideration was the layout of our array. We basically could do one of three things; put the LEDs in series, parallel, or a combination of the two. With the LEDs in a series combination, the current through every LED would be the same, and the voltage across the whole string would be the sum of the voltage drops across each diode. The most attractive aspect of the series string is that the current is the same. The brightness of the LED is directly proportional to the current through it. With the current in the array the same, every LED would be the same brightness. The problem with a series connection is that if one LED was to burn up or fail, the entire string would turn off. With a parallel connection, the voltage across each diode is the same, and the current is divided among each LED. The benefit of the parallel connection is that if one LED were to fail, the other LED in the array would still stay on. The problem with the series string is that it takes a lot of current. If we were going to have an array of twenty LEDs, operating at one amp, we would need 20 amps. The best way to connect the LEDs is with a combination of both series and parallel. Have a series string of parallel connected LEDs. This way the current requirements aren't as great, and the string won't turn off if one LED fails. However, do to constraints of our current driving chip, we ultimately chose to go with a series connected LED string.

The next thing we needed to consider was how to get from 120 volts AC to a desirable DC voltage. To change AC to DC, there are a number of different types of rectifiers, either using some MOSFETS or diodes. Because we are only using the DC voltage to power our LEDs, the diode rectifier is the best fit because it is the cheapest.

Considering what converter we need to step down the 120v DC to whatever value we need to power our array, we need to consider cost, flexibility (how easy will lit be to obtain different voltages), and size. Our converter needs to be small enough to conceal in our enclosure.

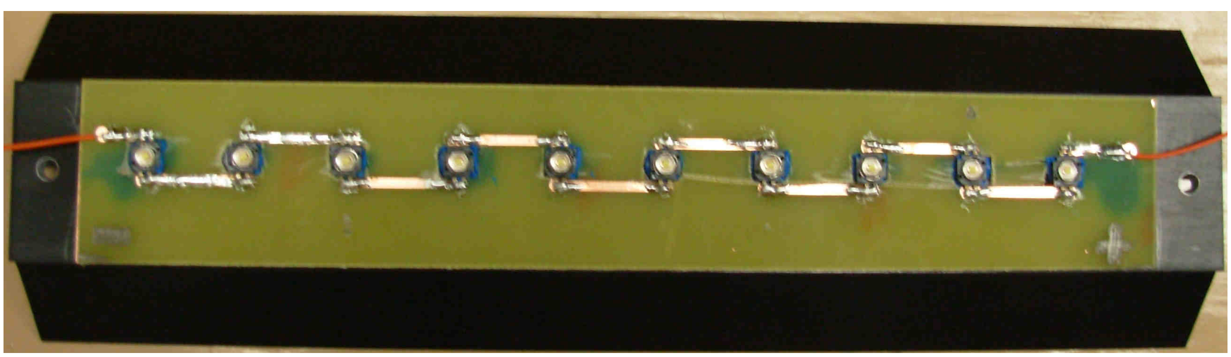
For our controller we needed to find the best way to vary the brightness of our LED string. As mentioned earlier, the brightness in our LEDs depends on the current through the diode. So varying the current through the diode will vary the brightness. We would also like to do this without dissipating any power. We want our string to be as efficient as possible. One of the problems with varying the current to vary the brightness is that the brightness and the current are related by an exponential. If the dimmer was a dial, the brightness wouldn't change vary much in the first half of a turn, but it would

change vary rapidly in the next quarter of a turn. The brightness would not change linearly. One way to counter this problem is to utilize the LED's properties of being able to turn on and off very quickly and use pulse-width modulation. With pulse width modulation, you essentially operate the string with pulses run on a clock. If you want full brightness, the pulse would just be a straight line at whatever voltage we were operating at. If we wanted the brightness to be 90% the full brightness the pulse would be on 90% of the time and off the other 10%. This way the change in brightness would be linear.

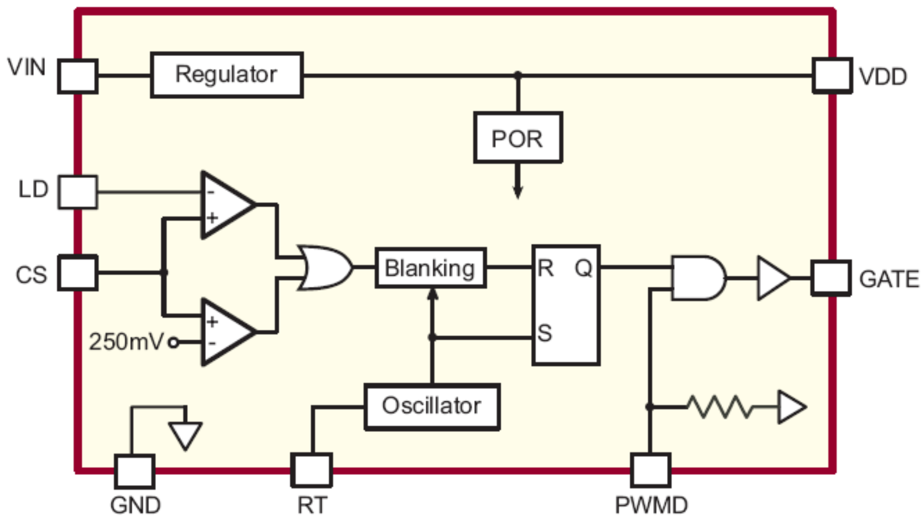
Our string is going to operate from AC voltage source from the wall. Therefore it will be susceptible to power surges and other anomalies, so it will need to be protected. The current and the voltage are related, so protecting against over-current will protect against over voltage, however, the current will also increase, as the LEDs get hotter, remaining at a constant voltage. So protecting against over-voltage will not necessarily protect against over-current. Currently on the market there are many options to protect against over current. There are fuses, circuit breakers, and even chips designed to shut the circuit off at desired currents. These different options vary in price, convenience, how complicated it will be to implement. These will all be factors in choosing which way to go.

Final Design:

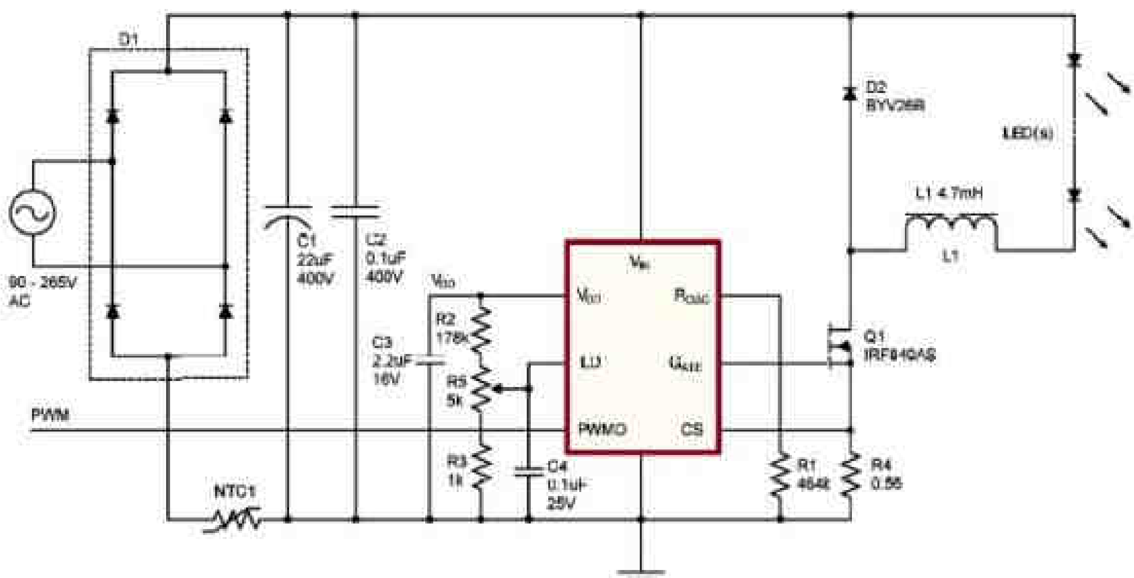
For our final design we decided to build our project around the Luxeon K2 Emitter. At the time of our research this diode was state of the art. One LED will produce 100 lumens at one amp. A standard light bulb produces 1740 lumens. So in order to surpass the light output of the light bulb we will create a string of 20 LEDs. Our LEDs have a viewing angle of 120 degrees, a lifespan of 50,000 hours, or 6 years running 24 hours a day, and require a heat sink. These LEDs are very small, and the pads that make the electrical connections on the LED are fragile. So to mount our LEDs to the heat sink, we made a PCB and cut holes in it to mount the PCBs in. The LEDs are adhered to the heat sink with thermal epoxy.



To supply power to the LED we chose to supply a constant current through the string. To implement this we chose Supertex's HV9910 HBLED driver. This chip utilizes a small current sensing resistor, and an internal voltage reference to set the current.

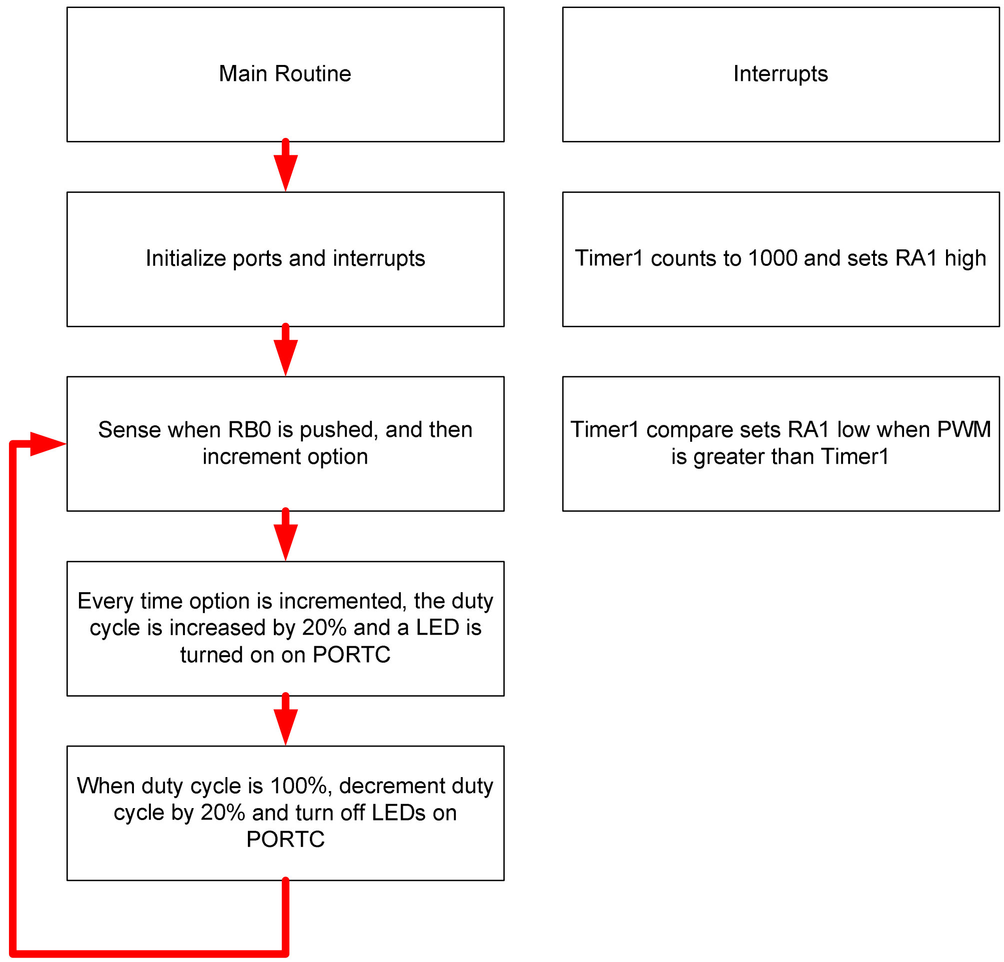


To set the current threshold to one amp, we select a current sensing resistor that will have a voltage drop of 250mV at one amp. This is what protects our LEDs from over current. The chip constantly checks the voltage at CS pin and turns the gate of the MOSFET when the threshold is exceeded. The rate that it checks is set by the resistance at the RT pin. If the switching frequency is too little, the Inductor in the buck converter will saturate, clamping the current, and if the switching frequency is too high, it could damage the chip. For our design we have a switching frequency of 100 kHz.

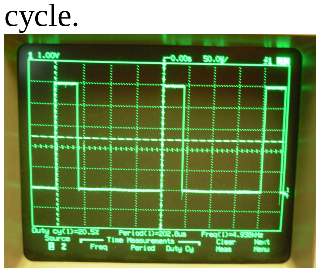


The chip takes a DC voltage, and then turns the gate of the MOSFET on and off to get a constant current. The chip also includes a Pulse Width modulation that allows you to decrease the current through the String.

To get a variable duty cycle square wave we wrote code and implemented it with a PIC.

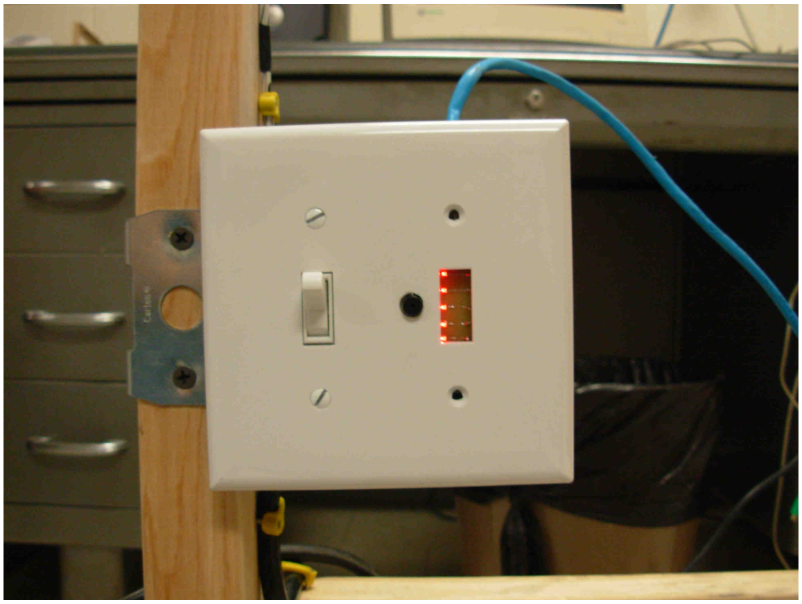


Our code uses two interrupts to generate the PWM signal. Timer one sets RA1 high, and repeatedly counts to 1000. Timer one compare turns RA1 off when the variable PWM is greater then the count on RA1. By adjusting the value of PWM we can change the duty cycle to anything we want. Our main routine initializes the ports and turns the interrupts on, then an infinite while loop continuously senses RB0. When RBO is pressed a variable option is increased. The PIC starts with RA1 turned off, and no LEDs on port C turned on. With the first push of RBO on LED turns on on port C, and RA1 outputs a 20% duty cycle.

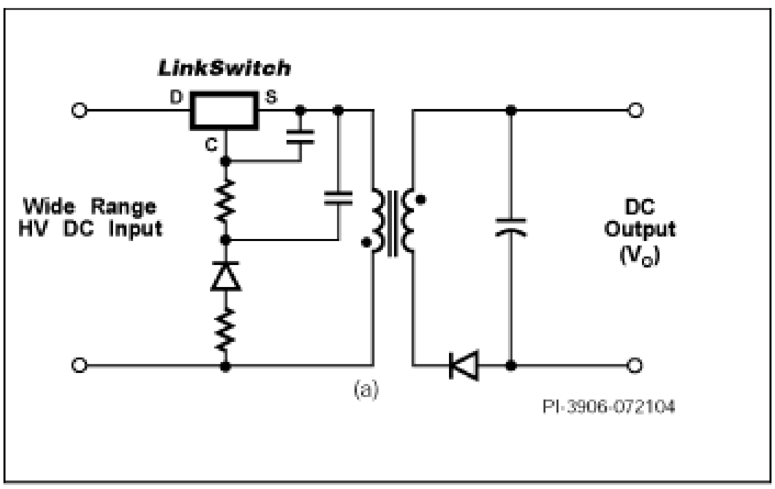


Every push of RB0 turns on another LED and increments the duty cycle by 20% until there are five LEDs on and a duty cycle of 100%. After this state pressing the button turns off LEDs on port C and decreases the Duty cycle.

Our PIC provides indication to the user to indicate the level of brightness. We ran Ethernet cable from our PIC to the switch in the wall to turn on small LEDs as the Brightness of the LEDs increased.



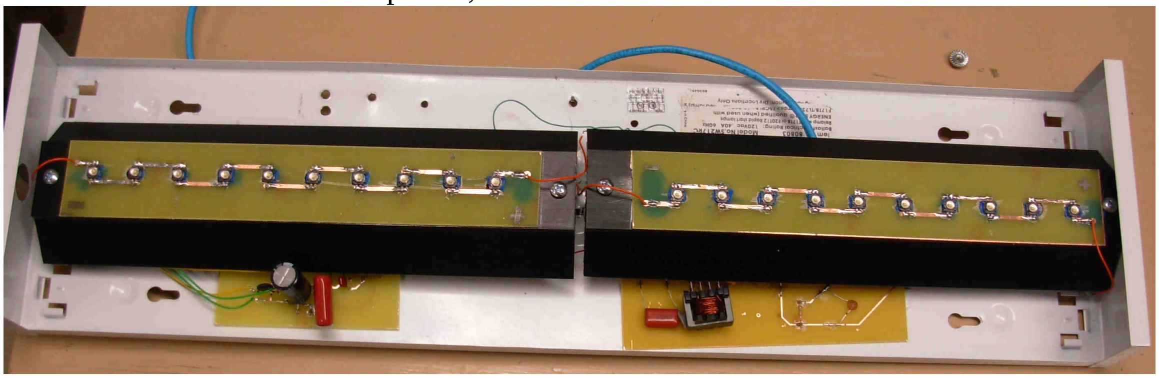
To have our PIC control the current, it will need to run off of 120VAC. In order to achieve this we used the LNK500. The LNK500 is a high frequency switching DC-DC converter.



The chip takes rectified AC voltage, then acts as a buck converter, and also uses a small transformer to drop the voltage down to five volts.

For our final enclosure, we retro-fitted a two foot fluorescent tube enclosure that was donated to us by Lowes. The AC wires come in through the end of the enclosure and

connect to the rectifier that is mounted in the enclosure. Our heat sinks with the LEDs are mounted in the enclosure on spacers, so we can fit the PCBs underneath them.



Test Results:

One of our requirements was to compare light output, efficiency, cost, and life expectancy of all current forms of lighting with our LED array. To effectively compare the different light sources we needed a way to measure the light output. We were able to acquire a Minolta Photo Meter that measured light output in lux. The lux is a unit based on lumens. One lux is equal to one lumen per square meter. The lux takes into account the area over which the luminous flux is spread.

To test our LED fixture, we used the photo meter to measure the lux produced at 2 feet from the fixture and 6 feet from the fixture. For comparison, candlelight at 1 foot produces 10 lux, a hallway/restroom is around 80 lux, and a brightly lit office is around 400 lux. The data below shows our LED fixture output compared to a 100W incandescent bulb and two 32W 4 foot fluorescent tubes.

- 20 Luxeon K2 Emitter 65 Watt (1000mA)
  - 2 feet: 1040 lux
  - 6 feet: 150 lux
- General Electric 100 Watt Incandescent
  - 2 feet: 260 lux
  - 6 feet: 80 lux
- 2 Starcoat 4’ 32 Watt Fluorescent Tube (64 Watts)
  - 2 feet: 1040 lux
  - 6 feet: 260 lux

Lighting Source	Lifespan (hours)	Lumens/Watt	Total Cost to Operate 50,000 hours (dollars)
LED Fixture	50,000	26.89	$353.40
100W Incandescent	1,000	17.4	$417.45
Two 32W Fluorescent Tubes	5,000	60	$438.60

Problems Encountered and Lessons Learned:

Throughout our design process we encountered many problems, and in turn learned a lot. One problem we encountered was the input on our PIC was very sensitive. I added button chatter protection in the code, but that didn't protect against false triggering. The input sensitive to static voltage, if you touched the PIC anywhere near RB0, the PIC would go crazy. To solve this, we had to put an R-C filter at the input.

We originally planned to use the VDD pin of the HV9910 to supply the five volts needed to power the PIC, however the PIC drew too much current for the low voltage side of the chip to handle. So instead of using the VDD pin we had to Use an external voltage regulator like the LNK500.

Our initial build of the HV9910 circuit had a few flaws. It initially had an output current much lower than what we wanted. One cause of this was that our switching frequency was too low, and our inductor was saturating. Increasing our switching frequency greatly increased our output current. However, we still were not getting the desired one amp output. After consulting with the people at Supertex we found that the comparator at the CS pin is sensitive, and sometimes requires an R-C filter at the pin. Adding this filter brought the current to the value that we intended. One reoccurring problem we encountered, was unintentionally hooking our circuit to earth ground. Because our circuit doesn't have isolation from the AC-mains, connecting earth ground to any location on our circuit wreaked havoc. When our product is fully enclosed and secured in the wall, there shouldn't be any way to unintentionally connect our circuit to earth ground.

Future Improvements:

Like any finished project there is always room for improvement. One easy improvement and probably the most dramatic would be to use more state-of-the-art LEDs as they come out on the market. When we were researching what LED to choose, our K2-Emitter was top of the line supplying 100 lumens at one amp. In just four months they now make a LED that produces 200 lumens at one amp.

One reason we chose to implement the PWM with a PIC was because of the many things you can do with a PIC. For instance we could have a motion sensor near our LED string to sense when nobody is around, and turn the LEDs off, or dim them to save energy. Another thing we could do with the PIC would be to create a temperature sensor and put it by the LEDs. The sensor could tell the PIC to turn off the LED string if they ever got too hot.

Trouble Shooting:

No light output

1. Press the button on the switch – if no indicator lights lit
    a. Check connections of Ethernet wire
2. Check Connections of Switch
    a. Tighten down screws
3. Make sure Power is being supplied to switch
    a. Check to make sure fuse or circuit breaker is ON
4. Fixture may be defective contact manufacture for more support

No indicator Lights – But Light is ON

1. Check RJ-45 Jack termination for non-connected wires on both ends
    a. Re terminate Ethernet connection
2. Switch may be defective contact manufacture for more support

Budget:

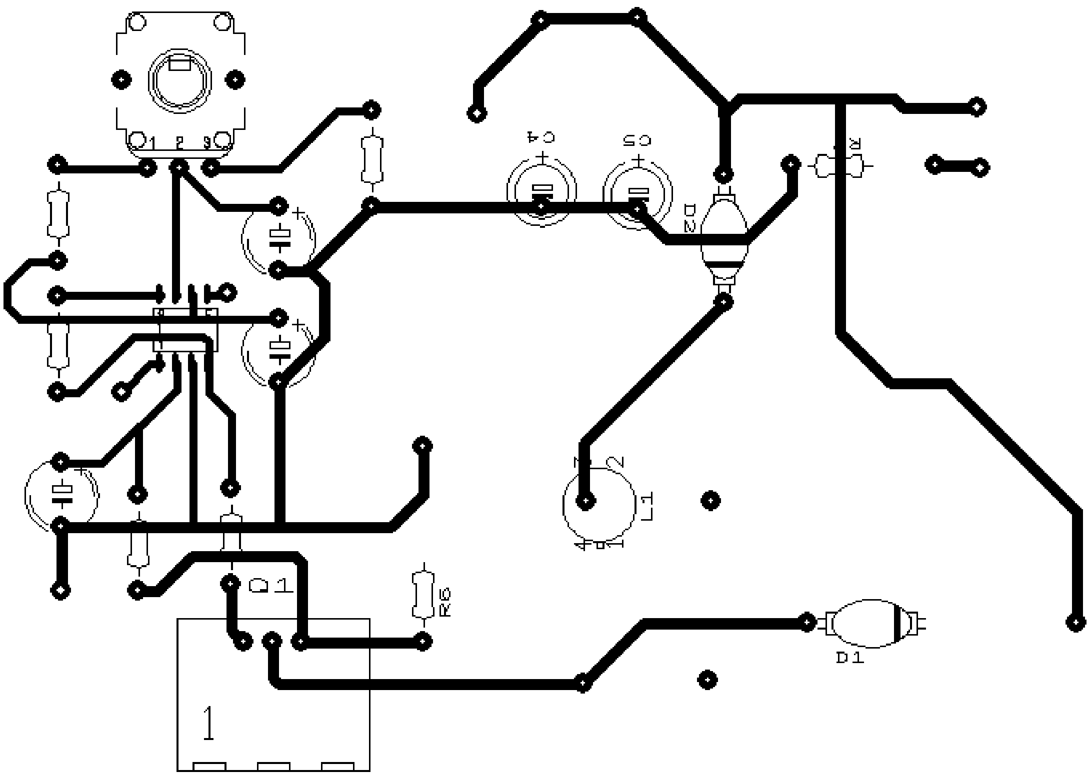
Date	Company	Quantity	Parts	Retail Per unit	Aquired Per Unit	Retail price	Aquired Price	Shipping	Aquired Price+ Shipping
11/27/2007	Fututre Electronics	20	Luxeon K2 Emmiter LEDS	$ 4.67	$ 4.67	$ 93.40	$ 93.40	$ -	$ 93.40
11/27/2007	Digi- Key	3	Inrush Current Limiter 50 Ohm 1.6A	$ 1.96	$ 1.96	$ 5.88	$ 5.88	$ -	$ 5.88
11/16/2007	Supertex	3	HV9910B Universal High Brightness LED Driver 16 pin	$ 1.15	$ 1.15	$ 3.45	$ 3.45	$ 5.00	$ 8.45
11/16/2007	Supertex	3	HV9910B Universal High Brightness LED Driver 8 pin	$ 0.94	$ 0.94	$ 2.82	$ 2.82	$ 5.00	$ 7.82
11/12/2007	Electronic precepts	2	Ther-O-Bond 1600 2 Part Epoxy	$ 12.56	$ 12.56	$ 25.12	$ 25.12	$ -	$ 25.12
11/9/2007	Digi-Key	1	Heat Sink	$ 27.00	$ 27.00	$ 27.00	$ 27.00	$ -	$ 27.00
11/9/2007	Digi-Key	1	Buck Convertor Parts - RLC Componets	$ 19.18	$ 19.18	$ 19.18	$ 19.18	$ -	$ 19.18
11/6/2007	Newark	15	IRF840 Power Switching Mosfets	$ 0.35	$ 0.35	$ 5.30	$ 5.30	$ -	$ 5.30
10/21/2007	Future Electronics	20	Luxeon K2 Emmiter LEDS	$ 4.65	$ 4.65	$ 93.06	$ 93.06	$ -	$ 93.06
10/15/2007	Digi-Key	10	RJ-45 Jacks	$ 2.70	$ 2.70	$ 27.00	$ 27.00	$ -	$ 27.00
10/15/2007	Jameco	1	3 debounce buttons, 10 22pf ceramic Capacitors	$ 1.78	$ 1.78	$ 1.78	$ 1.78	$ -	$ 1.78
9/28/2007	Supertex	3	HV9910B Universal High Brightness LED Driver	$ 0.94	$ 0.94	$ 2.82	$ 2.82	$ 10.00	$ 12.82
5/2/2007	Future Electronics	10	Luxeon K2 Emmiter LEDS	$ 3.45	$ 3.45	$ 34.50	$ 34.50	$ 9.00	$ 43.50
				$ -	$ -	$ -	$ -	$ -	$ -
Free									
4//2007	Advanced Thermal Solutions	1	LED Heat Sink	$ 28.00	$ -	$ 28.00	$ -	$ 15.00	$ 15.00
11/1/2007	Lowes	1	2 Ft Flourescent Light	$ 20.00	$ -	$ 20.00	$ -	$ -	$ -
		1	Dual Gang Switch Face Plate	$ 1.50	$ -	$ 1.50	$ -	$ -	$ -
		1	Dual Gang Wall Box	$ 2.16	$ -	$ 2.16	$ -	$ -	$ -
		1	Light Switch	$ 0.59	$ -	$ 0.59	$ -	$ -	$ -
11/9/2007		4	8 ft Pine 2"x4"	$ 1.68	$ -	$ 6.72	$ -	$ -	$ -
	Yuvarajan	1	LNK500 + RLC parts	$ 10.00		$ 10.00			
Totals				**$145.27**	**$ 81.34**	**$410.28**	**$341.31**	**$ 44.00**	**385.305**
				Under Budget					

Appendix: Code

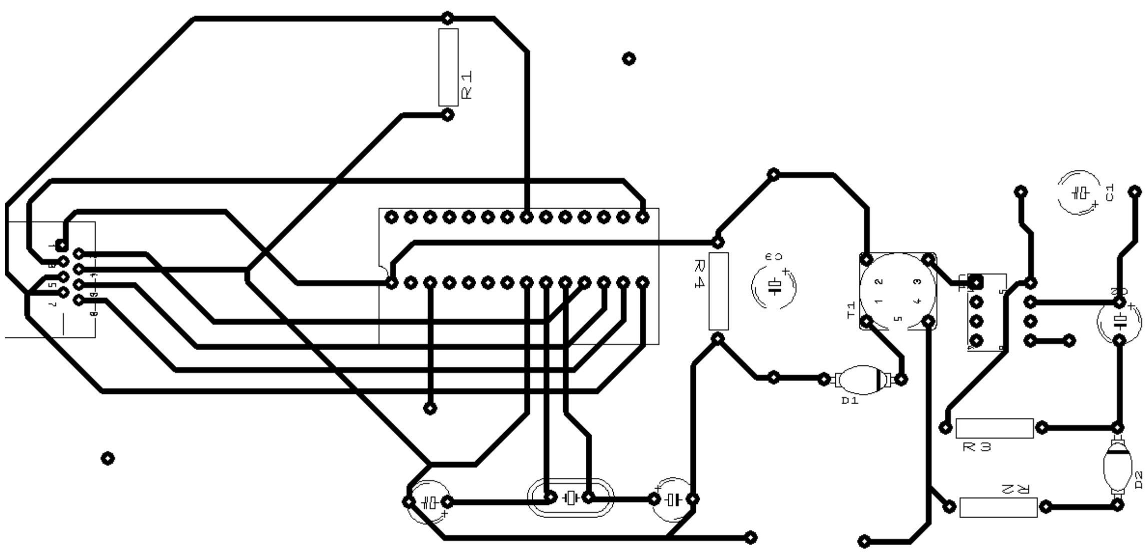
```
// Global Variables
unsigned int count, PWM,
pulse, Option;
static volatile unsigned int
TIMER1 @0x0E;
static volatile unsigned int
CAPTURE1 @0x15;
// Subroutine Declarations
#include	<pic.h>
#include	"bootloader.c"
#include	"function.c"


void interrupt IntServe(void)
@ 0x10
{
if(TMR1IF){
TIMER1=-1000;
if(Option >= 1){
RA1 = 1;}
else RA1=0;
CAPTURE1=PWM;
TMR1IF=0;}

if (CCP1IF == 1) {
CCP1IF = 0;
RA1 = 0;
}
  }
void Wait(long int X)
{
   unsigned int i;
   for (i=0; i<X; i++) {
      }
   }

// Main Routine

void main(void)
{

   unsigned char Mode;
   unsigned int Time;
   unsigned char Phase;
   unsigned int j,i;

   TRISB = 0xFF;          //
RB0, RB1 are inputs
   TRISC = 0x00;          //
PORTC is output
   TRISA= 0x00;
   PORTC = 0;             //
turn off the LEDs
   Option = 0;


   TMR1CS=0;
   TMR1IE=1;
   TMR1ON=1;
   PEIE=1;
   CCP1CON=0x0A;
   CCP1IE=1;
   CAPTURE1 = 0;
   GIE=1;


   do {


      if ( Option >= 10)
Option=0;

      if ( Option==0)
                {PORTC=0x00
;
                RA1=0;
                PWM=-999;
                                }

      if ( Option==1)
                {PORTC=0x01
;
                RA1=pulse;
                PWM=-800;
                                }

      if ( Option==2)
                {PORTC=0x03;
                RA1=pulse;
                 PWM=-600;
                                }

      if ( Option==3){
            PORTC=0x07;
              RA1=pulse;
               PWM=-400;
                                }

      if ( Option==4)
              {PORTC=0x0F;
              RA1=pulse;
               PWM=-200;
                                }

      if ( Option==5)
              {PORTC=0x1F;
               RA1=pulse;
              PWM=1000;
                                }
                  if (
Option==6)
              {PORTC=0x0F;
              RA1=pulse;
              PWM=-200;
                                }
                  if (
Option==7)
              {PORTC=0x07;
               RA1=pulse;
              PWM=-400;
                                }
                  if (
Option==8)
              {PORTC=0x03;
               RA1=pulse;
              PWM=-600;
                                }
                  if (
Option==9)

                {PORTC=0x01
;
               RA1=pulse;
               PWM=-800;
                                }



   while(!RB0);
            Wait(1000);
   while(RB0);
            Wait(1000);
 Option += 1;
               // the program
runs
     } while (1>0);
   }
```

PCB Layouts

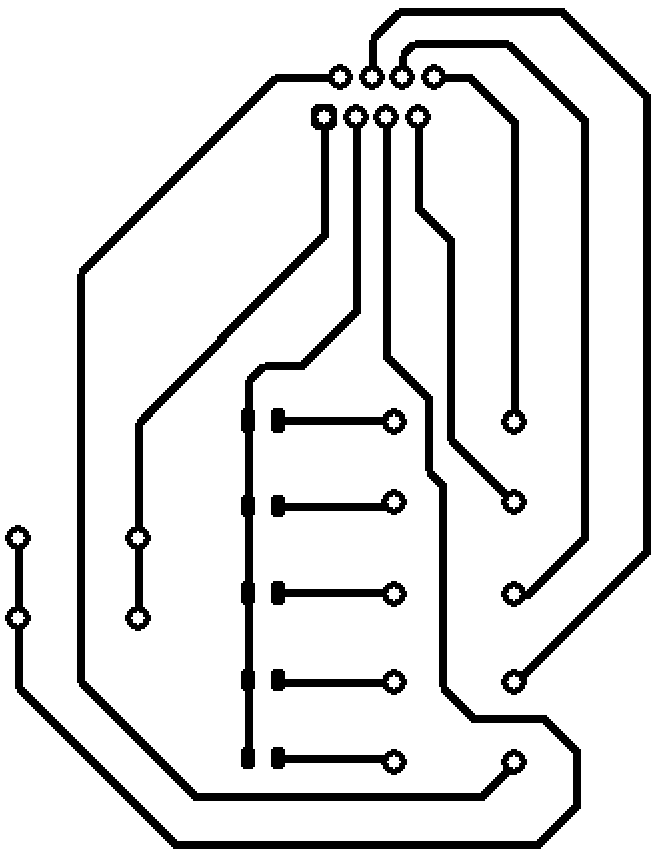
HV9910



PIC and Switching Converter Board Layout



Indicator Switch Board Layout



Datasheets

Supertex inc. **HV9910B**

Universal High Brightness LED Driver

Features

- Switch mode controller for single switch LED drivers
- Enhanced drop-in replacement to the HV9910
- Open loop peak current controller
- Internal 8.0V to 450V linear regulator
- Constant frequency or constant off-time operation
- Linear and PWM dimming capability
- Requires few external components for operation

Applications

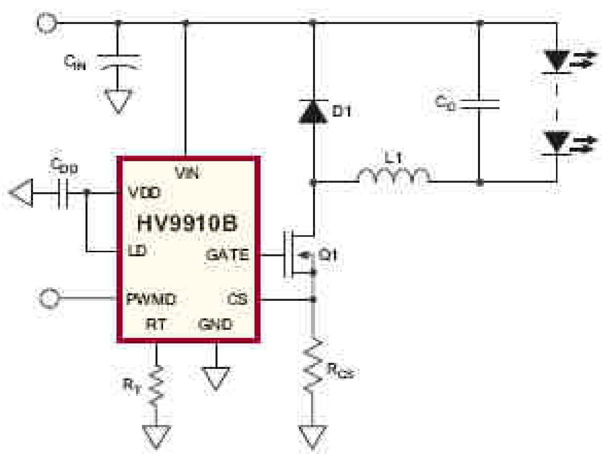
- DC/DC or AC/DC LED driver applications
- RGB backlighting LED driver
- Back lighting of flat panel displays
- General purpose constant current source
- Signage and decorative LED lighting
- Chargers

General Description

The HV9910B is an open loop current mode control LED driver IC. The HV9910B can be programmed to operate in either a constant frequency or constant off-time mode. It includes an 8 – 450V linear regulator which allows it to work from a wide range of input voltages without the need for an external low voltage supply. The HV9910B includes a PWM dimming input that can accept an external control signal with a duty ratio of 0 – 100% and a frequency of up to a few kilohertz. It also includes a 0 – 250mV linear dimming input which can be used for linear dimming of the LED current.

The HV9910B is ideally suited for buck LED drivers. Since the HV9910B operates in open loop current mode control, the controller achieves good output current regulation without the need for any loop compensation. PWM dimming response is limited only by the rate of rise and fall of the inductor current, enabling very fast rise and fall times. The HV9910B requires only three external components (apart from the power stage) to produce a controlled LED current making it an ideal solution for low cost LED drivers.

Typical Application Circuit



LNK500

LinkSwitch® Family

Energy Efficient, CV or CV/CC Switcher for Very Low Cost Adapters and Chargers

POWER INTEGRATIONS

Product Highlights

Cost Effective Linear/RCC Replacement

- Lowest cost and component count, constant voltage (CV) or constant voltage/constant current (CV/CC) solution
- Extremely simple circuit configuration
- Up to 75% lighter power supply reduces shipping cost
- Primary based CV/CC solution eliminates 10 to 20 secondary components for low system cost
- Combined primary clamp, feedback, IC supply, and loop compensation functions – minimizes external components
- Fully integrated auto-restart for short circuit and open loop fault protection – saves external component costs
- 42 kHz operation simplifies EMI filter design

Much Higher Performance Over Linear/RCC

- Universal input range allows worldwide operation
- Up to 70% reduction in power dissipation – reduces enclosure size significantly
- CV/CC output characteristic without secondary feedback
- System level thermal and current limit protection
- Meets all single point failure requirements with only one additional clamp capacitor
- Controlled current in CC region provides inherent soft-start
- Optional opto feedback improves output voltage accuracy

EcoSmart® – Extremely Energy Efficient

- Consumes <300 mW at 265 VAC input with no load
- Meets California Energy Commission (CEC), Energy Star, and EU requirements
- No current sense resistors – maximizes efficiency

Applications

- Linear transformer replacement in all ≤3 W applications
- Chargers for cell phones, cordless phones, PDAs, digital cameras, MP3/portable audio devices, shavers, etc.
- Home appliances, white goods and consumer electronics
- Constant output current LED lighting applications
- TV standby and other auxiliary supplies

Description

LinkSwitch is specifically designed to replace low power linear transformer/RCC chargers and adapters at equal or lower system cost with much higher performance and energy efficiency. LNK500 is a lower cost version of the LNK501 with a wider tolerance output CC characteristic. *LinkSwitch* introduces a revolutionary patented topology for the design of low power switching power supplies that rivals the simplicity and low cost of linear adapters, and enables a much smaller, lighter, and attractive package when compared with the traditional "brick." With efficiency of up to 75% and <300 mW no-load consumption, a *LinkSwitch* solution can save the end user enough energy over a linear design to completely pay for the full power supply cost in less than one year. *LinkSwitch* integrates a 700 V power MOSFET, PWM control, high voltage start-up, current limit, and thermal shutdown circuitry, onto a monolithic IC.

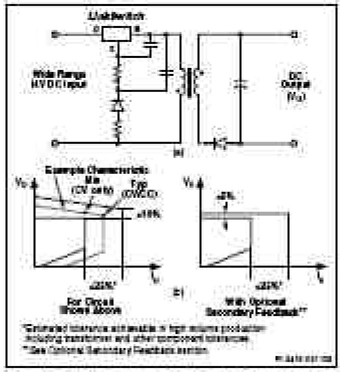


Figure 1. Typical Application – Not a Simplified Circuit (a) and Output Characteristic Tolerance Envelopes (b).

OUTPUT POWER TABLE[1]					
PRODUCT[4]	230 VAC ±15%		85-265 VAC		No-Load Input Power
	Min[2]	Typ[3]	Min[2]	Typ[3]	
LNK500 P or G	3.2 W	4 W	2.4 W	3 W	<300 mW
	4.3 W	5.5 W	2.5 W	3.5 W	<500 mW[3]

Table 1. Notes: 1. Output power for designs in an enclosed adapter measured at 50 °C ambient. 2. See Figure 1 (b) for Min (CV only designs) and Typ (CV/CC charger designs) power points identified on output characteristic. 3. Uses higher reflected voltage transformer designs for increased power capability – see Key Application Considerations section. 4. For lead-free package options, see Part Ordering Information.

MICROCHIP

PIC16F87X

28/40-pin 8-Bit CMOS FLASH Microcontrollers

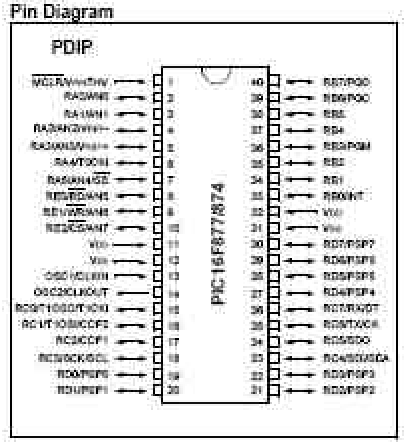
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory, Up to 368 x 8 bytes of Data Memory (RAM) Up to 256 x 8 bytes of EEPROM data memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial and Industrial temperature ranges
- Low-power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

Pin Diagram



Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master Mode) and I²C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

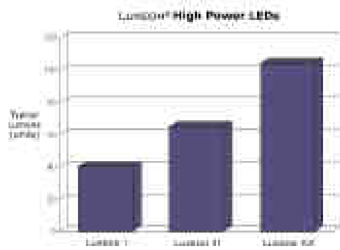
Technical Datasheet DS51

LUXEON
never before possible

power light source

LUXEON® K2 Emitter

Introduction



LUXEON® K2, the latest addition to the LUXEON high-power LED family, establishes elevated standards for light output, thermal management, and manufacturability. Offering industry-leading lumens per package and power handling capabilities, LUXEON K2 enables you to create never before possible lighting applications and:

- deliver more useable light
- optimize applications to reduce size and cost
- engineer more robust applications
- reduce thermal management engineering
- utilize standard FR4 PCB technology in addition to MCPCB solutions
- simplify manufacturing through the use of surface mount technology.

LUXEON K2 Technology Leadership

- Highest operating junction temperature available, 185°C
- Industry leading lumen performance, > 140 lumens in 6500K white
- Highest Drive Currents—1500 mA
- Lowest Thermal Resistance—9°C/W
- Industry Best Moisture Sensitivity level—JEDEC 2a
  4 week floor life without reconditioning
- Lead free reflow solder JEDEC 020c compatible
- RoHS Compliant
- Autoclave compliant—JESD22 A-102
- Industry Best Lumen Maintenance—50,000 hours life at 1000 mA with 70% lumen maintenance

LUXEON® K2 is available in white, green, blue, royal blue, cyan, red, red-orange and amber.

PHILIPS

LUMILEDS
LIGHT FROM SILICON VALLEY

ECE 405

High Brightness LED Control

Ryan Kuschel, Chris Schrom, Alex Weigel

Advisor: Dr. Yuvarajan

December 7, 2007

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